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Forest Health Protection

Pacific Southwest Region

File 3420
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Date: July 29, 2003

Subject: Disease and Insect Conditions in Stand 106, Downieville Ranger District, Tahoe National Forest (FHP Evaluation NE03-05)

To: District Ranger, Downieville Ranger District, Tahoe National Forest

At the request of Carla Kempen (Assistant District Culturist, Downieville RD) Forest Health Protection (FHP) evaluated the insect and disease conditions in Stand 106 on the Downieville RD. The objective was to provide input to Carla on disease and insect activity in Stand 106 and how this activity might effect proposed vegetative management projects for Stand 106. Bill Woodruff (FHP Plant Pathologist) examined Stand 106 first on March 3, 2003 and then a second time on June 10 with John Kliejunas (FHP Region 5 Plant Pathologist). The first examination was conducted with Carla and the second with Carla and Terri Walsh (District Silviculturist, Downieville RD).

The root disease fungi *Heterobasidion annosum* and *Armillaria* spp. were confirmed in the Douglas-fir and white fir, but not in pine. The two root diseases may be acting together or in sequence to infect Douglas-fir and white fir trees of all ages. This root disease complex is evident in stumps and in roots of uprooted trees in several locations in the stand. Stem and butt decay fungi *Phellinus pini* and *Phaeolus schweinitzii* were also present. Incidental occurrences of white fir dwarf mistletoe , western gall rust on young ponderosa pine and Douglas-fir bacterial gall were found. Old evidence of western pine beetle mortality on a ponderosa pine snag and fir engraver mortality on white fir logs were also found.

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Existing Condition

Carla Kempen provided the following description for Stand 106:

> This is an "old forest" mixed conifer stand. Tree species consist mainly of Douglas-fir with a moderate amount of sugar pine, white fir, incense-cedar, and tanoak, and a small amount of black oak with a few ponderosa pine. There are a few scattered predominate Douglas-fir and sugar pine with an average dbh of 50". The remaining large black oak are in poor condition. There are small, scattered pockets of annosus and armillaria which have created standing snags and large down logs. There is moderate to heavy areas of Phellinus pini in the Douglas-fir. Tanoak is present in understory, ranging from light to heavy. Canopy cover averages 69 percent. Average stand diameter is 19" dbh.

Proposed Silvicultural Prescription

Carla is proposing the following preliminary prescription for Stand 106. The prescription is constrained by the direction given in the Sierra Nevada Framework FEIS for old forests that are in the Threat Zone of the Urban Wildland Interface.:

> To reduce ladder fuels, remove suppressed and intermediate conifers from 10 to 20" dbh. Remove some codominant conifers up to 20" dbh where they are crowded and crowns are overlapping. Increased spacing between crowns would stimulate growth on the remaining trees and reduce the risk of a crown fire. Remove conifers from around large black oak (> 8" dbh) with full crowns. Do not remove conifers that are intertwined within black oak branches or that may damage the black oak when felling. Do not remove healthy sugar pine. Maintain at least 49 percent canopy cover on the average throughout the stand. In areas larger than 1 acre in size where the average diameter exceeds 24" dbh and canopy cover exceeds 40 percent, limit removal to trees less than 12 dbh

Insect and Disease Occurrences

Stand 106 is an old growth stand with many very large conifers, snags and natural stumps. No large conifer stumps from past logging activity were observed. One incense-cedar snag with an estimated dbh of 96 inches was found (Fig. 1). Stand 106 has a number of diseases that are associated with old growth forests. Advanced bole decay is common in the old Douglas-fir, ponderosa pine and sugar pine as indicated by the numerous *Phellinus pini* conks found on some of the largest Douglas-fir, sugar pine and ponderosa pine. (Fig. 2). Advanced root decay, caused by a disease complex of *Heterobasidion annosum* and *Armillaria* spp., is likely present in a number of Douglas-fir and white fir. Advance decay, delaminating roots of wind-thrown Douglas-fir (Fig. 3) and white fir, was found in Stand 106. This decay is often an indicator that annosus root disease is

present. However, to confirm the presence of specific root decay fungi, signs of the pathogen need to be found, or the pathogen needs to be isolated from host tissue.

Armillaria spp. rhizomorphs (Fig. 4) and *Heterobasidion annosum* conks/fruiting bodies (Fig. 5) were found on Douglas-fir and white fir in Stand 106, confirming the presence of Armillaria and annosus root diseases. These two fungi appear to be jointly or sequentially infecting some of the Douglas-fir and white fir as a disease complex. Since both Armillaria and annosus root disease pathogens can colonize and decay roots or portions of roots in Douglas-fir and white fir without killing the hosts, it is difficult to estimate the severity of the root disease in Stand 106. The foliage and crowns of most of the Douglas-fir and white fir appear healthy, indicating that the root decay in these trees is probably not severe.

Two strains of *H. annosum* are known to exist in the US. The s-type (spruce type) is the strain that infects Douglas-fir, true firs and giant sequoia. The p-type (pine type) infects most pines, incense-cedar, some shrubs, and a few hardwoods. P-type has been known to occasionally infect s-type hosts, but not vice-versa. No *H. annosum* was found in ponderosa pine in Stand 106, so it is assumed that the s-type annosus is the pathogen.

Armillaria spp. can infect most conifers in the western United States as well as many hardwoods. In general, *Armillaria* spp. lives as a decay organism in the roots, lower boles, and stumps of either dead or living trees. Black oak is known to be a host, so *Armillaria* spp. is most likely present in the black oak in Stand 106. Cutting black oak trees can provide a food base for *Armillaria* spp. to infect conifers more aggressively. This phenomenon has been especially evident in conifer plantations. The effects of these diseases can be reduced by thinning the trees and removing competing shrubs in order to enhance tree vigor and growth.

Incidental occurrences of four other pathogens and two forest insects were found in stand 106. None of these appears to be significantly affecting the stand or the individual trees within the stand. One fruiting body of *Phaeolus schweinitzii* was identified. *P. schweinitzii*, 'velvet top fungus', causes red-brown butt rot on Douglas-fir, pines, white fir and incense-cedar. This pathogen is often associated with old growth conifers. Western gall rust, caused by *Peridernium harknessii*, was found on a number of ponderosa pine saplings. White fir dwarf mistletoe, *Arceuthobium abietinum* (form species *concoloris*) was seen on a few white fir trees. Bacterial gall (Fig. 6) was seen on the branches of a few old Douglas-fir. Galleries of the fir engraver, (*Scolytus ventralis*) were found on a number of fir logs and western pine beetle (*Dendroctonus brevicomis*) galleries were identified on the inner bark of one older ponderosa pine snag. Both these beetles infest and kill stressed trees. The observed mortality was light, and probably occurred in the early 1990s during the extended drought that occurred then in northern California.

A stem canker on a sapling sugar pine was suspected to be caused by *Cronartium ribicola*, but fruiting was not observed to confirm the presence of white pine blister rust. Several madrone and tanoak leaves with symptoms reminiscent to Sudden Oak Death were collected and sent to the CDFA lab. Results were negative.

Lastly, it was observed that the trees growing in the eastern portion of Stand 106 were smaller and had thinner crowns. Stocking also appeared less dense. This poor growth was first thought to be the result of the annosus/armillaria root disease complex that was observed in decayed roots of occasional logs elsewhere in the stand. However, no signs of root decay or pathogens could be located. Further examination revealed that activities associated with mining had disturbed the soil in a portion of the poor-growth area. Differences in soil appearance prompted Carla to recheck the soil map of the area. The soil in this poor-growth area is indeed different, with shallower rooting depth and a lower available water capacity than the rest of the stand. This difference explains the observed differences in stand growth.

Management Implications

As expected in an old growth stand, there are a number of pathogens present in Stand 106. The pathogens that could impact future management are *Heterobasidion annosum, Armillaria* spp. and *Phellinus pini*. Signs of annosus and Armillaria root diseases were found in several locations in the stand on decaying stumps and roots. The best treatment for root and stem disease in a stand where clearcutting is not an option, is to maintain vigorous growth by thinning trees and removing shrub competition. Since we cannot be sure which roots are not infected, all freshly cut conifer stumps should be treated with the fungicide, Sporax® to prevent introducing *H. annosum* into healthy roots. In treating Armillaria root disease, it is important not to kill black oak because *Armillaria* spp. that is living on the oak can move to nearby conifer roots when the oak roots die.

Advanced decay from *Phellinus pini,* as indicated by the large number of conks growing on a number of old Douglas-fir, sugar pine and ponderosa pine, will continue to increase and weaken the infected trees. At some point each affected tree will fail, probably when stressed by a strong gust of wind. Removing nearby trees which are sheltering any tree with advanced root, butt or bole decay will subject the weak trees to wind gusts which may topple them. For this reason, if it is necessary to remove trees to meet management objectives, it is wise to first remove the trees with visible conks (*P. pini* or *Phaeolus schweinitzii*) or with unhealthy appearing crowns which might indicate advance root decay in the absence of any known insect or disease problem.

The fact that bark beetles and fir engraver have been active in the past indicate that portions of Stand 106 were overstocked. Insects will continue to kill trees in this stand whenever trees become stressed. Often beetles will not only kill stressed trees, but also adjacent trees because the

beetles often target areas of trees and not individuals. Maintaining stocking levels where trees don't become stressed during extended periods of below moisture can minimize future beetle caused mortality.

Following this report are biological summaries for some of the diseases and insects discussed and copy of Forest Service Handbook, FSH 3409.11, on annosus root disease. If you need further assistance, please do not hesitate to call me at 252-6680.

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Plant Pathologist

FIGURES

Figure 1. Incense-cedar snag

Figure 2. *Phelinus pini* fruiting bodies/conks

Figure 3. Decayed Douglas-fir roots

Figure 4. *Armillaria* spp. rhizomorph

Figure 5. *Heterobasidion annosum* conk

Figure 6. Bacterial gall on Douglas-fir branch

APPENDIX

Annosus Root Disease

Heterobasidion annosum is a fungus that attacks a wide variety of woody plants. All western conifer species are susceptible. Madrone (*Arbutus menziesii*), and a few brush species (*Arctostaphylos* spp. and *Artemisia tridenta*) are occasional hosts. Other hardwood species are apparently not infected. The disease has been reported on all the National Forests in California, with incidence particularly high on true fir in northern California campgrounds. Incidence is somewhat higher in older, larger fir stands and in stands with high basal areas (over about 330 square feet/acre).

During periods favorable to the fungus, fruiting bodies (conks) form in decayed stumps, under the bark of dead trees, or under the duff at the root collar. New infection centers begin by aerial spread of spores produced by the conks and subsequent colonization of freshly cut stump surfaces or wounds on living trees. The fungus then spreads through root contacts into the root systems of adjacent live true fir. Local spread of the fungus from a stump typically results in the formation of a disease center, with dead trees in the center and fading trees on the margin. These centers usually continue to enlarge until they reach natural barriers such as stand openings or non-susceptible plants.

In pines, *H. annosum* grows through root cambial tissue to the root crown where it girdles and kills the trees. In less resinous species such as true firs, the fungus sometimes kills trees, but more frequently it is confined to the heartwood and inner sapwood of the larger roots where it causes a chronic butt and root decay and growth loss. Thus, while infection in true fir usually does not kill the host, it does affect its growth and thriftiness. Losses in true fir from *H. annosum* are mainly the result of windthrow resulting from root decay, and reduced root systems which predispose trees to attack and eventual death by the fir engraver beetle. Field observations suggest that vigorous young firs are usually able to regenerate root tissues faster than they are lost to the root disease. But when true firs slow in growth because of stand and/or site conditions, root development decreases to where there is a net loss in roots and the trees slowly decline due to the gradual loss of their root systems. This decline may take 10 to 20 years before tree death occurs.

In general, infections will cross from roots of pine to roots of true fir; however, rarely is the fungus observed to cross from true fir to pine. At higher elevations where pine and true fir are intermixed, *H. annosum* is commonly found only on true fir and mortality rarely includes both species within an infection center.

Armillaria Root Disease

Armillaria spp. is widely distributed in soils and usually lives as a saprophyte on dead wood or other organic matter. This fungus has a wide host range, including virtually all woody plants in California. It is frequently associated with hardwood roots, especially oaks. Healthy oaks are resistant to the fungus. This resistance disappears, however, when trees are weakened, stressed, cut, or killed, and *Armillaria* spp. may then rapidly colonize and decompose roots and sometimes entire root systems. Stresses that have been linked to increased damage from this root disease include insect defoliation, drought, excessive soil moisture, poor planting techniques, bark beetle attack, air pollution injury, and nutrient deficiencies.

The organic material used as a source of nutrition is called a food base. With a large food base to utilize, the fungus becomes more aggressive and moves to the roots of nearby trees by means of

root contacts and rhizomorphs. Rhizomorphs are structures that resemble black shoestrings and grow like roots through upper soil layers. The predominant method of tree to tree spread in California is via root contact; rhizomorphs are more important and prevalent in other areas of the country.

Armillaria spp. is capable of directly penetrating through the intact root bark of living trees and once it reaches the cambium it usually grows rapidly, producing a flat, white, leathery, fan-shaped mycelial mat. Rhizomorphs are often associated with the mat. If the fungus reaches the root collar it girdles the stem and kills the tree. After *Armillaria* spp. successfully colonizes a root segment or root system, it continues to decay the wood and causes a white to yellowish, wet, stringy rot. This rot does not usually extend more than a few feet above the soil line.

Clusters of mushrooms may be found in the fall at the base of infected dead or dying trees and stumps. These mushrooms may also grow directly out of the soil near the food base. Spores produced by fruiting bodies are not an important source of new infections or long distance spread.

Phellinus pini

Red ring rot, also called white pocket rot, is caused by a wood decay fungus, *Phellinus* (*Fomes*) *pini*, that attacks Douglas-firs, pines, true firs, hemlock, and rarely incense-cedar. It occurs throughout the coniferous forests of the world, and is the single most damaging heart rot organism in the West.

Red ring rot attacks young-growth as well as old-growth trees. It usually infects through branch stubs, and rarely through open wounds. Thus, this fungus may cause serious heart rot problems in managed stands of the future.

The perennial, woody fruiting bodies or conks that arise from the branch stubs or knots of living trees are the best indicators of decay. Sometimes only punky knots bearing the inner portion of the fruiting body remain on the stem. These punky knots may later be overgrown by new wood, becoming swollen knots that are the only symptom of decay. When conks or swollen knots are present, assume that advanced decay extends about 3-5 feet above and 5-7 feet below the indicator. If conks or swollen knots are visible along much of the stem, heart rot will be extensive.

White Fir Dwarf Mistletoe

White fir dwarf mistletoe, *Arceuthobium abietinum* f. sp. *concolor*, is a seed-bearing plant that parasitizes only white fir. It will not survive without living host tissue, which it depends on for support, food, nutrients, and water.

Dwarf mistletoes initiate their life cycle when a seed lands on a needle or small twig of a host. The seed is coated with viscin, a sticky substance that allows it to adhere to the host tissue. During rains, the viscin becomes mucilaginous, allowing the seed to slide down to the needle base where it may lodge. The seed germinates in the winter or spring and the radicle grows along the twig until it reaches a needle base or bark irregularity. The radicle forms a holdfast and penetrates the twig into the xylem. A type of root system then develops in the twig. In 3 to 5 years from seed deposition, most successful infections will appear as branch swellings and will bear mistletoe shoots. These shoots will not produce fruit until at least 5 years following seed deposition, the average being 8-9 years. Fruit mature in the fall and disseminate seed in September and October.

The seeds are explosively discharged from the fruit through the buildup of turgor pressure. Seeds normally have an upward trajectory.
True fir dwarf mistletoe does not spread rapidly following establishment. Vertical spread in a tree averages less than 3 inches per year. Horizontal spread in a stand without overstory infection is also quite limited. Dense foliage limits spread because of the high probability of interception of the seed. Spread from infected overstory to understory may be up to about 100 feet, but it is usually less; the actual distance is dependent on slope, wind, and other factors. Trees less than 3 feet tall have a very limited chance of infection because of their small target size.

Western Gall Rust

Western gall rust (*Peridermium harknessii*) causes branch galls and trunk cankers on nearly all species of hard pines. The rust fungus produces yellow to orange-colored spores (aeciospores) on the surface of the galls during cool, moist, spring weather the second or third year after infection. New crops of spores are produced yearly thereafter until the host tissue dies. Dispersal of spores by wind occurs usually in May and June. After spores land on susceptible tissues, especially after rainfall, some germinate and cause new infections. Most infections occur on current-year shoots. There is considerable yearly variation in the amount of infection in the West, where abundant infection in given stands occurs in relatively few years.

The fungus infects pines of all sizes and ages. Seedlings are the most susceptible and are often killed within a few years by girdling stem galls. In nurseries, galls may develop on seedlings as a result of infection by spores from surrounding infected stands and windbreak trees. Branch infections on mature trees usually are of slight importance; however, branch infections of highly susceptible trees may exceed 100 galls and consequently would reduce growth potential. Stem infections can result in growth loss and cull. Galls resulting in cankers may continue to grow slowly for more than 200 years eventually resulting in stem deformity. Cankers form weak points making stems and branches susceptible to wind breakage. Cankers also create avenues through which decay fungi can enter stems.

Red-Brown Butt Rot

The mushroom-like fruiting bodies of *Phaeolus schweinitzii* are the most reliable signs of infection. They are produced annually on the ground near the bases of infected trees. Occasionally, they occur on the stem, usually within 3 1/3m (10 ft) of the ground. They are velvety in texture and reddish, greenish, or yellow-brown with yellow margins. As they age, they become dark brown, brittle and resemble cow-pies. Early decay is light green to light brown and firm. In advanced stages, the decay is light brown and cubical, aging to dark brown with resinous white mycelial sheets in the shrinkage cracks.

P. schweinitzii is most frequently found infecting older Douglas-fir. Less frequently affected hosts include spruces, and Jeffrey, ponderosa, western white, and sugar pine. The fungus is found only rarely on western redcedar, hemlocks, and true firs.

P. schweinitzii causes severe root and butt decay of older trees. Wind breakage above the groundline is more common than windthrow. Trees are seldom killed as a result of root decay alone, but this does sometimes happen. Douglas-fir beetles and *Armillaria* spp. often attack *P. schweinitzii*-infected trees. Decay is confined to the heartwood and is usually found in the roots and butts of the host within ten ft (3 1/3 m) of the ground. However, decay may occasionally extend as much as 30 ft (10 m) up the trunk in trees greater than 150 years of age. Infected trees may have pronounced butt swells. In very advanced cases, the heartwood may disintegrate completely, leaving a hollow butt. Trees in this condition often fail during high winds.

The fruiting bodies are produced in summer and fall, and may persist for a year or more. They tend to be more abundant on moist sites. Fruiting bodies near the bases of trees indicate that the roots are infected but do not necessarily indicate that extensive butt rot is present. Windborne spores colonize trees through root wounds and fire scars. Tree to tree spread also takes place across root contacts and grafts. The relative importance of these two different modes of infection varies by locality. Trees of any age may become infected.

Fir Engraver

The fir engraver, *Scolytus ventralis*, attacks both white and red fir in California. Trees ranging in size from large saplings to overmature sawtimber are susceptible. Attacks can cause patch-killing of cambium along the bole, top-kill, or tree death. Top-kill or death occur most often in firs that have been weakened by root disease, dwarf mistletoe, overstocking, soil compaction, sunscald, logging injury, or drought. The fir engraver also breeds in slash and windthrown trees.

The fir engraver usually completes its life cycle in one year, sometimes two. Adults fly and bore into trees or green fir slash from June to September; larvae, pupae, and adults over-winter under the bark. Pitch tubes are not formed as they are with pine bark beetles; the usual evidence of attack is boring dust in bark crevices along the trunk and pitch streamers on the mid and upper bole. Trees colonized early in the summer may begin to fade by early fall, but those colonized later in the year usually do not fade until the following spring or summer, often after the beetles have emerged.

Western Pine Beetle

The western pine beetle, *Dendroctonus brevicomis*, breeds in the main bole of living ponderosa and Coulter pine larger than about 4 inches dbh. Normally it breeds in trees weakened by drought, overstocking, root disease, dwarf mistletoe or fire. Adult beetles emerge and attack trees continuously from spring through fall. Depending on the latitude and elevation, there can be from one to four generations per year. The generations are difficult to distinguish because the prolonged period of initial attack and re-emergence of parent females to establish additional broods causes considerable overlapping of the generations.

Initial attacks are made about mid-bole and subsequent attacks fill in above and below. Pheromones released during a successful attack attract other western pine beetles. Attacking beetles may spill over onto nearby apparently healthy trees and overwhelm them by sheer numbers. Pitch tubes and red boring dust are indications of successful attacks.

Adults bore a sinuous gallery pattern in the cambium and the female lays eggs in niches along the sides. The larvae feed in the inner bark for a short distance and then turn into the outer bark to complete development.

Bluestain fungi introduced during successful attacks probably contribute to the rapid mortality associated with bark beetle attacks. Woodpeckers, predaceous beetles and low winter temperatures cause natural control. Silvicultural activities that result in rapid, vigorous tree growth increases tree resistance and prevents mortality. Individual high value trees undergoing a temporary reversible stress, such as drought, can be protected for up to a year by applying insecticides to the bole.

FSH 3409.11 - FOREST PEST MANAGEMENT HANDBOOK

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CHAPTER 60 - MANAGEMENT OF SPECIFIC PESTS

62 - DISEASES.

62.2 - Other Diseases.

1. Introduction to Annosus Root Disease. This section describes annosus root disease in the Pacific Southwest Region, and discusses the biology and resource management implications of the disease. It also presents guidelines and techniques for its detection, and management strategies available for reducing its impact.

Annosus root disease is one of the most important conifer diseases in the Region. Current estimates are that the disease infests about 2 million acres of commercial forest land in California, resulting in an annual volume loss of 19 million cubic feet. Potential impacts of the disease include: increased susceptibility of infected trees to attack by bark beetles, mortality of infected trees presently on the site, the loss of production on the site, and, in recreation areas, depletion of vegetative cover and increased probability of tree failure and hazard. In recreation areas, annosus-infected trees are often extremely hazardous, causing death or injury to visitors, and damage to permanent installations and property.

The goal of annosus root disease management in the Region is to reduce resource losses to levels which are economically, aesthetically, and environmentally acceptable when measured against the objectives of the resource manager. It is possible to reduce the impact of annosus root disease through detection, evaluation, prevention, and suppression. These activities must progress in a planned, timely sequence for successful reduction of annosus root disease impacts. Detection and evaluation in individual stands are normally necessary before undertaking prevention and suppression action. In developed recreation sites, early recognition and removal of hazardous annosus-infected trees is critical, and will greatly improve chances of preventing future damage with minimal site deterioration. Prevention is the most desirable means of reducing losses. Undertake suppression activities only when needed to supplement prevention measures. The basic guidelines for detection (FSM 3410), evaluation (FSM 3420), prevention (FSM 3406.1) and suppression (3406.2) for any insect or disease also pertain to annosus root disease. However, consider the additional specific guidelines for annosus root disease summarized in this section.

Annosus root disease occurs on a wide range of woody plants. The disease affects all western conifers; hardwoods are generally resistant or immune. All the National Forests in Region 5 have reported finding it. Incidence is particularly high on Jeffrey pine in southern California recreation sites and on Jeffrey and ponderosa pine in eastside pine type forests. The disease, endemic in the Red and White Fir forest types, is associated with one-fifth or more of the true fir mortality in the forests surveyed in northern California.

2. Biology.

a. Heterobasidion annosum (Fomes annosus) causes annosus root disease. The fungus is similar to the common heartrot fungi, and forms fruiting bodies or conks in decayed stumps, under the bark of dead trees, or, rarely, under the duff at the root collar.

Infection centers start when airborne spores produced by the conks land and grow on freshly cut stump surfaces. Infection in true fir may also occur through fire and mechanical wounds on the butt. Fresh basal wounds on species other than true fir are rarely colonized. The fungus grows down the stump into the roots and then spreads through root contacts into the root systems of adjacent live trees, resulting in the formation of enlarging disease centers. These infection centers may continue to enlarge until they reach barriers, such as openings in the stand or groups of resistant plants. In pines, the fungus grows through root cambial tissue to the root crown where it girdles and kills the tree. In true fir and other non-resinous species, the fungus sometimes kills trees, but is more frequently confined to the heartwood and inner sapwood of the larger roots. It then eventually extends into the heartwood of the lower trunk and causes chronic decay and growth loss, or failure at the roots. References that discuss the biology and disease cycle of H. annosum include Otrosina and Cobb 1989, and Smith 1993.

Heterobasidion annosum in western North America consists of two intersterility groups, or biological species, the 'S' group and the 'P' group. These two biological species of H. annosum have distinct differences in host specificity. To date, all isolates of H. annosum from naturally infected ponderosa pine, Jeffrey pine, sugar pine, Coulter pine, incense-cedar, western juniper, Pinyon, and manzanita are of the 'P' group. Isolates from true fir and giant sequoia are of the 'S' group. The biological species infecting other hosts are unknown at this time.

This host specificity is not apparent in isolates occupying stumps, with both the 'S' and 'P' groups recovered from pine stumps, and the 'S' group and occasionally the 'P' group from true fir stumps. These data suggest that infection of host trees is specific, but saprophytic colonization of stumps is not. The fungus may survive in infected roots or stumps for many years. Young conifers of a species that is susceptible to the particular intersterility group established near these stumps often die shortly after their roots contact infected roots in the soil.

Invasion of freshly cut stump surfaces by germinating spores is a critical stage in the disease cycle. Conks produce spores which disseminate throughout the year, but H. annosum is dependent on favorable environmental conditions for successful germination and establishment. Spores are inactivated by ambient temperatures of 113º F (45ºC) and mycelium in wood is killed after exposure for one hour at 104º F (40ºC). Temperatures just below the stump surface commonly reach or exceed the thermal inactivation level (40º C) of mycelium from April to September in the Southeastern United States. In eastside pine on the Lassen National Forest, lethal temperatures reach above 40ºC in the top 6 inches of 6-inch diameter stumps when exposed to direct sunlight for several days in the average summer. Temperatures do not approach the lethal range in larger size classes of stumps.

Stumps are susceptible to infection immediately after cutting. Ponderosa pine, Douglas-fir, and coast redwood stumps remain susceptible to infection for 2 to 4 weeks. The decrease in susceptibility with time is probably a result of colonization of the stumps by microorganisms that compete with and replace H. annosum. Surface area infection of freshly cut ponderosa pine stumps increases with increased photochemical oxidant injury.

Vertical penetration depends on temperature and extent of injury from other sources. After germination, vertical penetration into pine stumps averages 3 inches/month from October through May and 5 to 6 inches/month from June to October. The rate of vertical penetration in stumps from pine trees severely injured by photochemical oxidants is greater than in those from slightly injured or uninjured trees.

Heterobasidion annosum is an important agent predisposing conifers to bark beetle attack. In pines, the fungus weakens trees and increases their susceptibility to pine bark beetles. Infected true firs are predisposed to attack by the fir engraver. White fir mortality from the annosus root disease-fir engraver complex frequently occurs after tree growth decreases because trees are stressed. As a result of the stress, it is suspected that roots grow very slowly and decay faster than the tree can replace them. This predisposes the tree to fir engraver attack, and causes its death.

3. Detection. The general distribution of annosus root disease in the Pacific Southwest Region is known, but information on its location in specific stands may be needed. Based on Region-wide surveys, it is prudent to assume that the pathogen is present in all true fir stands, unless a detailed survey suggests that it is not. Collect location information for stands when planning management activities. Because trees affected by annosus root disease are easily windthrown or fall without visible symptoms that might warn forest recreation managers of impeding failure, the number, size, and locations of annosus infection centers within developed sites or sites planned for development should be determined. Field surveillance and detection surveys will locate occurrences of H. annosum.

4. Field Surveillance. Forest workers and managers, in connection with their regular duties, carry out day-to-day field surveillance (FSM 3411). Stand examinations, inventories and other activities afford excellent opportunities for forest workers to note and record the presence of H. annosum.

A systematic search for diagnostic symptoms of infection and signs of the pathogen, determines the presence of H annosum. Use the following similar symptoms for correct diagnosis:

a. Pattern of Dying Within the Stand. Root pathogens tend to kill trees over a period of years, with oldest deaths at the center, usually around stumps, and recently dead and dying trees at the margin. In contrast, a characteristic of mortality by bark beetles alone is groups of trees dying at about the same time.

b. Pattern of Dying of Individual Trees. Trees with root disease die gradually, with symptoms progressing from the bottom of the crown upwards, and from the inside of the crown out. Infection of the roots causes: (1) reduced height growth, with crowns becoming rounded; (2) thin and chlorotic crowns, resulting from poor needle retention; and (3) subsequent insect attack of the stressed trees.

c. Symptoms and Signs in Roots and Root Crowns. Use symptoms and signs in roots and root crowns to determine the specific identity of the pathogen. The best evidence of H. annosum is the presence of characteristic fruiting bodies or conks. The annual to perennial, leathery conks vary in size and shape from small button-shaped or "popcorn" conks on the root surface of recently killed seedlings or saplings, to large bracket-type conks. The large conks generally have a light brown to gray upper surface, and a creamy white lower surface with regularly spaced, small pores. Small "popcorn" conks appear as small buff-colored pustules that range in size from a pinhead to a dime.

They often have no pore layer. In pines, the conks are found between the bark and wood on stumps, beneath the duff layer at the root crown, and within old stumps. In true fir, the conks are found in cavities hollowed out by the fungus. Conks may be abundant in some stands and scarce or absent in others. Even when present, they can be easily overlooked because of their inconspicuous color and obscure location. Refer to Hadfield, et al. 1986 and Smith 1993 for color photographs of conks.

On pines, additional symptoms may be found by exposing the roots and root crown and examining the inner bark. Choose recently killed or dying trees for examination. Indications of H. annosum infection are: (1) easy separation of the bark from the wood; (2) the separated surfaces are a light brown to buff color, the surface of the wood streaked with darker brown lines; and (3) numerous small silver to white flecks on the surface of the inner bark. Resin often heavily infiltrates infected roots.

Incipient or early stages of wood decay are not very diagnostic. Discoloration may or may not be present and the heartwood remains firm and hard. As the decay progresses, the wood becomes white to straw yellow, separates along annual rings, and may contain elongated white pockets.

If field personnel are unable to identify H. annosum with certainty, or desire confirmation of a tentative identification, the Forest Pest Management Group can assist. Gather specimens of infected root tissue in various stages of decay and any fruiting bodies and send them to FPM pathologists in the Service Areas, or to pathologists in the Regional Office. The specimens must be of tissues in early stages of decay to enable isolation of the pathogen. A completed Forest Pest Detection Report (Form R5-3400-1) shall accompany the samples.

5. Detection Surveys. Personnel may conduct detection surveys (FSM 3412) in areas where no other surveys are scheduled and it is essential that the presence or absence of annosus root disease be known for management purposes. The objective of a detection survey is simply to determine the presence and location of H. annosum.

Because annosus root disease is not always obvious and can be difficult to detect, contact the Forest Pest Management Group with a request to conduct the survey if H. annosum has the potential to adversely affect activities or interfere with resource objectives.

6. Evaluation. The purpose of a biological evaluation (FSM 3421) is to provide information for the resource manager on annosus root disease infestations, their affects on the stand, the management alternatives appropriate in the context of the particular resource management objectives, and the future affects of each alternative. The Forest Pest Management Group or field personnel shall conduct biological evaluations of annosus root disease. Submit requests for a biological evaluation by sending a Forest Pest Detection Report (Form R5-3400-1) or written request to the Regional Forester or FPM Program Leader, or to one of the Service Areas. Field units shall coordinate requests through the appropriate line officer.

7. Management Strategies. Use the integrated pest management (IPM) approach to manage annosus root disease and other pests. IPM involves regulating the pest, the host, and the environment to minimize pest impacts on resource management objectives in ecologically and economically sound ways. Also, use the IPM approach to implement and coordinate activities needed to prevent or suppress pest-related problems. This approach also emphasizes the selection, integration, and use of a variety of tactics on the basis of anticipated economic and ecological consequences. Accomplish control of annosus root disease by prevention of new disease centers,

thereby decreasing the risk of stump and wound infection, and through silvicultural manipulation of infested stands to minimize the impact of the disease.

8. Prevention. Prevention (FSM 3406.1) includes activities designed to minimize the impact of a pest before it appears. The objective of annosus root disease prevention is to prevent establishment of the disease in stands. Once annosus root disease becomes established in most forest stands, no economically feasible procedure for directly suppressing the disease is available. Therefore, prevention is the most efficient and economical method of reducing the impact of H. annosum. Prevention of annosus root disease includes treatment of freshly-cut conifer stumps with registered products. Other preventive treatments include carrying out silvicultural activities to lessen stand susceptibility to the disease, and minimizing logging damage and mechanical injuries.

9. Stump Treatment. Personnel can reduce the probability of infection of freshly cut conifer stumps by the use of a surface stump treatment with registered products. Contact Forest Pest Management for currently registered and effective materials. Treatment of freshly cut conifer stumps with two borate products (sodium tetraborate decahydrate and sodium octaborate tetrahydrate) indicate at least 90% efficacy in preventing infection. The borate in the formulations is toxic to the spores of the fungus and prevents germination; it does not have an effect on existing infections. Apply the products according to label directions. For maximum effectiveness, it is imperative to apply the material as soon after felling as practical and that the application cover the entire stump surface and other areas where the bark has been knocked off. The requirement for application in timber sales and other non-force account work shall be part of the contract or cooperative agreement. A Regional C provision is available for inclusion in timber sale contracts.

R-5 FSM 2303 requires treatment of all conifer stumps in recreation sites. The same direction shall apply to other high value areas, such as progeny test sites, seed orchards, and areas of high value trees, such as giant sequoia groves. In eastside pine or mixed conifer type stands, where surveys have indicated high levels of annosus root disease, treatment of conifer stumps 12 inches or greater in diameter is highly recommended during chainsaw felling. When mechanical shearers are used, the minimum diameter should be reduced to 8 inches. These areas include the eastside pine and eastside mixed conifer types on the Modoc, Lassen, Plumas, Tahoe, Sequoia and Inyo National Forests; the Goosenest Ranger District, Klamath National Forest; and the McCloud Ranger District, Shasta-Trinity National Forests.

In all other areas, consider stump treatments on an individual stand basis. The line officer is responsible for the decision to treat freshly cut conifer stumps, and shall base that decision on information available for the specific situation in the particular stand in question. This information should include:

a. The objectives and management direction for the stand.

b. The level of annosus root disease currently in the stand or in nearby similar stands, determined by an examination of stumps for evidence of H. annosum and indications of infection in living trees.

c. An estimate of the cost-effectiveness of the treatment.

d. A Forest Pest Management biological evaluation or an on-site visit.

10. Avoiding Cambial Damage. In addition to being an aggressive colonizer of freshly-cut stumps, H. annosum can also act as a wound parasite by attacking living trees through injuries that expose cambial tissue. The fungus, as well as other decay fungi, are likely to colonize logging injuries, especially those in contact with the ground. Trees with nonresinous wood, such as true fir and hemlock, are more likely to be infected following injury and to have more extensive decay than species with resinous wood, such as Douglas-fir and the pines. Decay caused by H. annosum is common behind fire scars and other basal wounds in true fir. It may be possible to minimize losses by preventing fires that expose cambium when underburning for fuels reduction, and by reducing mechanical injuries during stand entries.

Other methods of prevention have been suggested, but consider these methods experimental until there is demonstrated efficacy under California conditions. These experimental methods include: (1) thinning during the hotter summer months; (2) creation of high stumps, and, (3) control of stocking density in true fir stands.

11. Suppression. Suppression (FSM 3406.2) of annosus root disease includes the reduction of damage to acceptable or tolerable levels. Direct suppression procedures for H. annosum, such as stump removal, creation of buffer strips, and soil fumigation, are costly and considered experimental. Indirect suppression options, that is, those that alter conditions favoring the pest through the application of silvicultural methods of stand manipulation, are available. These methods include species conversion, thinning in true fir stands, and in recreation areas, thinning and interplanting with hardwoods.

a. Species Conversion. Because of host specificity of the 'S' and 'P' types of H. annosum, favor the non-infected host species (see item 2.a.). In mixed conifer stands with infected true firs, the stand my be converted to pines and incense-cedar with little risk of subsequent infection. If pines are infected, favor true fir. In recreation areas, favor existing hardwoods or the non-infected conifer species. Since hardwoods are resistant, the fungus will eventually die out over a period of 2 to 4 decades, depending on stump size. Then, take steps to regenerate the conifers.

b. Thinning in True Fir Stands. Field observations suggest that removal of slow growing fir and thinning of overstocked stands to increase tree vigor may reduce the impact of the disease, given that the residual trees are capable of responding to release.

c. Revegetate Disease Centers. If consistent with site-specific objectives, resistant species can be used to revegetate active annosus centers. Leaving the centers barren or revegetating with hardwoods will allow the fungus to eventually die out over a period of several decades or more. Favoring hardwoods already present and planting suitable hardwoods provides a barrier of nonsusceptible roots that may limit the spread of infection centers. Thin dense pole-sized stands of susceptible conifers and interplant with hardwoods. Doing this minimizes opportunities for root contact and reduces the risk of further spread. It also increases tree vigor, which reduces risk of bark beetle attack.

d. Stump Removal. Removal of stumps and roots infected with H. annosum would reduce the amount of inoculum of the fungus on the site, and allow for earlier successful revegetation of the site with susceptible conifers. Stump removal as a suppressive method is being tested in several recreation sites, and its efficacy has not yet been demonstrated.

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